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BUSINESS CYCLES: THEORY, EVIDENCE AND IMPLICATIONS

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ABSTRACT

This paper looks at recent advances in the study of aggregate fluctuations. Our emphasis is on three prominent areas of research: the stochastic growth model, economies which exhibit macroeconomic complementarities and models that emphasize heterogeneity. Each section of the paper outlines the theory, discusses relevant empirical evidence and then discusses some implications of the analysis.

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I. Introduction

The point of this paper is to bring together positive and normative aspects of ongoing research on the sources and consequences of aggregate fluctuations. My approach will be to look at the interaction between models of fluctuations and policy in two ways. First, from the positive perspective, does the consideration of government policy bring the predictions of the models closer to the data? As we shall see, this is a particularly relevant for real business cycle models. Second, what do these models suggest as the appropriate form of intervention?

While there are numerous active areas of investigation into the sources and consequences of business cycles, here we focus on three: real business cycles, models built on macroeconomic complementarities and models with non-convexities and heterogeneity. I have chosen to highlight these models partly due to their prominence in the ongoing debate over the aggregate fluctuations and partly due to the unique perspective they bring to policy questions.

Each of the subsequent sections of the paper is organized around one of these models. An initial fairly detailed example of each model is supplemented by a discussion of the empirical implications of the model relative to the evidence. Finally, and perhaps most importantly in light of the conference theme, the policy implications of these models are emphasized.

II. Stochastic Growth Models

Kydland-Prescott [1982] is undoubtedly the intellectual starting point of this branch of macroeconomics. With its emphasis on complete contingent markets and techonology shocks (broadly defined) as the primary source of fluctuations, the Kydland-Prescott paper spawned a literature built around a framework commonly termed the "real business cycle" model, hereafter RBC model. For the purposes of this presentation, with its emphasis on policy, the starting point of our discussion will be a variant of the RBC model which emphasizes fiscal policy. The discussion then turns to versions of the stochastic growth model with other policy shocks.

(i) Basic RBC model with Fiscal Policy

Imagine an economy composed of a large number of infinitely lived individuals all solving for an optimal consumption and capital accumulation path as in the classical one-sector growth model. The production function for each agent has the usual arguments of capital and labor as well as an exogenous technological parameter which, at least initially, will be the source of fluctuations in the economy.

Consider adding to this basic RBC model a government which produces a public good and finances its expenditures through a variety of taxes. A general specification of this problem is contained in Braun [1994] and will be the starting point for our presentation.

The optimization problem of a representative is given by:

$$\max E\left\{\sum_{t=0}^{\infty} \beta^t \, u(c_t, l_t)\right\} \tag{1}$$

where c_t is total period t consumption and l_t is period t leisure, β lies between zero and one and the utility function is strictly increasing and concave. Consumption in period t comes from two sources: private consumption (c_t^p) and government consumption (g_t). Braun assumes that these components enter linearly to determine total consumption: $c_t = c_t^p + \gamma g_t$ where γ is a parameter of the preferences. The household faces a time constraint that leisure plus work time (n_t) sums to the time endowment, normalized at 1. The transition equation for household capital (wealth) is given by:

$$k_{t+1} = k_t + (1-\tau_t)w_t n_t + (1-\tau_t)(1-\tau_t^k)(r_t-\delta)k + TR_t - c_t \tag{2}$$

In this expression, τ_t is the period t tax on income (both labor and capital) and τ^k_t is the period t tax on capital income, net of depreciation.[1] In (2), TR_t are lump sum transfers from the government.

The government is represented by its taxation and spending policies. Braun utilizes a statistical framework to capture government policy. In particular, income taxes, capital taxes and spending, along with a technology shock (described below) follow a stationary autoregressive process. Thus the model allows some feedback from the state of the system to government policy. In addition, the government is required to balance its budget each period. Thus the transfers are used to ensure that this budget balance condition is met.

Firms produce using a constant returns to scale technology in which output is produced from capital and labor. The production relationship is stochastic: there is a technology shock that is common to all firms. So, output is given by

$$Y_t = A_t F(K_t, N_t). \tag{3}$$

Households supply both inputs and all markets are competitive. The first order conditions for the firm relate the rental rate on capital (r_t) and the wage rate (w_t) to the marginal products of

[1] This tax structure reflects the double taxation of capital income in the U.S.

capital and labor respectively. The equilibrium conditions then guarantee that these factor prices clear markets using the predetermined capital level and the labor supply from the households.

The equilibrium is characterized by the following two necessary conditions:

$$u_2(c_t, 1-n_t) = u_1(c_t, 1-n_t)A_t F_2(k_t, n_t)(1-\tau_t) \tag{4}$$

$$\begin{aligned} &\beta E u_1(c_{t+1}, 1-n_{t+1})(1-\tau_{t+1})(1-\tau^k_{t+1}) \times \\ &[A_{t+1}F_1(k_{t+1}, n_{t+1})-\delta]+1) = u_1(c_t, 1-n_t) \end{aligned} \tag{5}$$

Intratemporal optimality is characterized by (4), taking into account the period t taxation of labor income The Euler equation for intertemporal optimality is given in (5) where the expectation is taken with respect to both the future state of technology as well as the future taxes on labor and capital income. These conditions are then supplemented by the government budget constraint, the individual budget constraint and the resource constraint that output equals consumption (private plus government) plus investment to fully characterize an equilibrium.

The properties of the optimal allocations are of interest in terms of assessing the quantitative implications of the model. A useful starting point is the model without fiscal policy: all spending and all taxes are set to zero each period.

It is quite well known that this model without fiscal policy does a good job of matching some observed movements in U.S. data.[2] In particular, the presence of technology shocks gives rise to procyclical productivity. The curvature of the utility function yields consumption smoothing so that the variance of consumption is less than the variance of output and the variance

[2] See Danthine-Donaldson [1993] and Fiorito-Kollintzas [1994] for a discussion of cross country evidence. Interestingly, investment is more volatile than output for all of the countries in the Danthine-Donaldson study but consumption is smoother than output in only 6 of ten cases.

of investment exceeds that of output. Further, there is procyclical movement in the labor input. From this perspective, the model does quite well in matching some characteristics of observed fluctuations.

However, Christiano-Eichenbaum [1992] argued quite persuasively that the standard real business cycle model failed to match the observed correlation in U.S. data between hours worked and average productivity. In particular, in U.S. data this correlation is about 0 while in most RBC models, including the standard KPR framework, the correlation is quite close to 1.[3] Further, for U.S. data, the variability in hours is close to that of output, contrary to the predictions of the initial RBC models.

In order to match the low correlations between hours and productivity, the labor supply curve must shift along with labor demand. Thus a one-shock model is unable to match observations. Christiano-Eichenbaum [1992] introduce stochastic fiscal policy into the analysis.

In particular, they consider a variant of model outlined above in which public and private consumption goods are imperfect substitutes ($\gamma \neq 1$). Government spending is financed by lump sum taxes: τ_t and τ^k_t are both set to zero and TR_t is negative so that spending is financed by lump sum taxes. Equivalently realizations of government spending are just subtracted from gross output in the resource constraint.

Christiano-Eichenbaum estimate rather than calibrate their model. For the extreme case in which government spending has no effect on individual's utility, fiscal policy has only pure wealth effects which do lead to variations in the labor supply curve of the representative agent. Periods of large government expenditures are matched with large wealth reducing taxes which increase

[3] Though, as emphasized by Christiano-Eichenbaum [1992], one must be very careful about the measurement of hours.

the labor supply of the individual household. Intuitively, from (4), increases in lump sum taxes, reduce consumption and thus increase the marginal utility of consumption, keeping savings fixed. This, in turn, increases the labor supply of the agent in order for the intratemporal condition to hold. Thus, it is through these labor supply effects that increases in govenment spending lead to increases in employment and output. Empirically, the model still substantially overstates the correlation between hours and average productivity.[4]

Braun [1994] takes this approach a step further using the structure outlined above. He admits differential taxation of capital and labor incomes and estimates the fiscal policy process using U.S. data where the tax rates are actually average marginal rates.[5] Braun finds that the labor income tax in quite persistent compared to the capital income tax.

The movement away from a specification in which government relies solely on lump sum taxation is important since increases in spending will now create substitution effects through the link between spending and distortionary taxes. In this regard, Braun finds that the correlation between government spending and hours is quite close to zero in a model economy with distortionary taxes while it is about .5 in an economy with lump-sum taxes only. This correlation is about .09 in U.S. data.

Braun finds that allowing for the taxation of capital and labor income, in a manner consistent with the time series representation of these taxes, brings the standard deviation of hours relative to output much closer to U.S. data. Further, the presence of these tax shocks creates enough variability in labor supply that the resulting correlation between hours and average

[4]Though Christiano-Eichenbaum do argue that their fiscal shock model combined with an elastic labor supply schedule cannot be rejected.

[5] In fact, many of the model's parameters are estimated using GMM though there is some structure imposed, such as log preferences over consumption and leisure.

productivity is actually negative as in U.S. data.[6] These results certainly support the view that taxes represent important shifters of labor supply.

Thus, from a positive perspective of inquiring about the properties of the stochastic growth model with taxation and government spending, we find that introducing these elements does enhance the capability of the model to match observations. In particular, some of the labor market anomalies, at least for the U.S., disappear upon the introduction of stochastic fiscal policy.

With regard to other countries, Danthine-Donaldson point out differences in labor market observations across countries. In fact, they emphasize that labor market observations are the least consistent across countries. In particular, they find that the correlation between productivity and employment is strongly negative for most countries in contrast to the U.S. correlation of near zero. Further, the correlation between employment and output, while positive, is much lower for countries other than the U.S.

Given the results of Christiano-Eichenbaum, Braun and McGrattan [1994], it is interesting to see if differences in fiscal policy processes can explain observed differences across countries. One recent effort along this lines is Jonsson-Klein [1996] who study the interaction between fiscal policy and the behavior of aggregate variables in Sweden. Jonsson-Klein consider a model with stochastic government spending, payroll taxes and consumption taxes. The latter seems particularly important in that consumption is slightly more volatile than output in Sweden. The model seems to do a very good job of matching this relative volatility as well as the near zero correlation between productivity and employment.

Besides being useful for bringing the RBC model closer to actual data, these models are

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[6] In fact, the point estimate of this correlation is even more negative than in U.S. data.

clearly instructive for policy exercises. Once these models are estimated, a variety of policy simulations can be performed as summarized by impulse response functions. Braun provides examples of this procedure highlighting the impact of temporary increases in income and corporate taxes. For example, using his estimated model, Braun finds that temporary increases in the income tax will lead to reductions in output, employment and consumption while government revenues will rise. Similar, but much smaller, movements are observed after an increase in the profits tax though in this case there is a temporary increase in consumption due to substitution effects induced by the temporary tax.

Baxter-King [1993] provides a very intuitive discussion of fiscal policy exercises which further illustrate the use of these models for policy analysis. Among other points, Baxter-King outline conditions for government expenditure multipliers in excess of unity arising from the dynamic interaction of capital and labor. Baxter-King also explore the effects of a balanced budget requirement, using distortionary income taxes. Their experiments reveal that temporary government expenditure increases lead to a reduction of output, consumption and investment when distortionary taxes must be raised to balance the budget.

Overall, these papers illustrate the capability of using the stochastic growth model to analyze fiscal policy. This framework can clearly be used to evaluate a wide variety of policies. Further, the model is based upon optimizing behavior and is internally consistent: there are no assumed decision rules or other restrictions on behavior imposed from outside of the model.

Still, one can certainly be unconvinced about the impact of fiscal policy from these exercises. First, the models clearly lack a variety of elements, such as market frictions, heteogeneity and so forth that some macroeconomists consider essential to any macroeconomic model. As we argue below, these ingredients can in fact be added to these models and these same policy exercises repeated in an alternative environment.

Second, one could be critical of the aforementioned exercises from the perspective that the fiscal policy functions do not emerge from a well specified optimization problem for the government. Put differently, one could inquire about the implications of optimal policy rather than focus on the consequences of a purely statistical representation of policy.

Not surprisingly, this approach is more difficult for a couple of reasons. Conceptually, one immediately faces the question of the basis for government intervention. Strictly speaking, there is no role for the government in the standard RBC model with complete markets, no externalities and so forth. Still, one could imagine the need for government spending (provision of public goods) comes into play though this is not really a stabilization role for the government. Thus any attempt to rationalize stabilization policy within this framework must be in terms of a model with frictions that create a welfare gain for policy, such as frictions in the labor market, imperfect competition, etc.[7]

A second difficulty emerges in the determination of optimal policy. If we actually model the government as a player in a dynamic economy, then it is natural to move away from a purely competitive framework in that the government is a large player. This immediately leads one into a consideration of commitment by this player.

The paper by Chari, Christiano and Kehoe [1994] is an important step forward in this research program. In particular, they characterize optimal fiscal policy in a version of the stochastic growth model assuming that the government is able to commit to its tax and spending

[7]For example, see Hairault, J-O., Langot, F. and F. Portier [1996] for a discussion of alternative means of financing unemployment compensation in a distorted environment.

policies. The policies they derive are quite different from those used in the fiscal policy exercises described above: labor taxes fluctuate very little and the ex ante tax on capital is close to zero. While the authors compare statistics from an economy with optimal policy to one more representative of actual U.S. policy, they do not present the labor market correlations. One would conjecture though that the model with optimal policy would not create enough labor supply variation to reduce the correlation between productivity and employment to zero.

The gap between this model and, for example, the analysis by Braun is troubling. If the underlying model of the economy and that of the policymaker is correct, then the positive and normative exercises ought to yield similar results. There are clearly two ways to go. First, the optimal policy problem studied by Chari et al. could be modified, perhaps to reflect additional constraints such as commitment on the policymaker. Second, the underlying economic model ought to be modified to give more of a role to the policymaker. That is, in an economy with frictions, the policymakers may have a larger stabilization role to play.[8]

Overall, on the fiscal policy side the stochastic growth model is clearly capable of being utilized for policy analysis. The framework advanced by Braun is rich enough to handle a variety of tax experiments, can be estimated and can be utilized for evaluating the impact of alternative policies. The results are intuitive and instructive.

(iii) Monetary and Financial Shocks

A final line of work within these models concerns monetary interventions. As has been well understood for quite a long time, any study of monetary policy must deal with two hurdles: generating a demand for money and creating a source of non-neutrality.

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[8] Hairault et al.[1995] study stabilization policy in an economy with frictions due to market power and liquidity constraints.

One approach is to study the liquidity effects of a monetary shock, as in Christiano-Eichenbaum [1992], Christiano, Eichenbaum and Evans [1996], Fuerst [1992] and Lucas [1990]. The idea is that a representative household is involved in a number of distinct activities: buying goods, selling labor, borrowing/lending and so forth. These models create a demand for money through some form of cash-in-advance constraint and the non-neutrality of money arises from lump sum transfers of new money directly to financial intermediaries. These funds flow from banks to firms to finance labor costs. Within this framework, money injections may lead to lower interest rates and expansions of activity. According to the quantitative analysis in Christiano-Eichenbaum [1992], the monetary shock also leads investment and consumption to move in opposite directions. Further, the basic models in this literature do not contain a mechanism to endogenously propagate these shocks.

Another possibility is to introduce wage and/or price stickiness as a basis for non-neutrality. Models illustrating the implications of assumed stickiness have been part of the macroeconomics literature for quite a long time. Theoretically, the well understood defect of these models is the lack of an explanation for the assumed rigidities. From the perspective of matching aggregate time series, the common versions of these models suffer in a number of ways. First, the models generally do not predict procyclical productivity. Second, monetary shocks generally do not have persistent effects in these models.

Recently, a number of papers have taken up the task of investigating both the source of the wage and price stickiness based upon strategic interactions. Further, making use of heterogeneity across price setters, it is also possible to produce some additional persistence. Since these results rest upon strategic interactions and heterogeneity, we delay their consideration until the next sections of the paper.

One of the activities of the monetary authority, at least in the U.S., is to regulate banking activity. It is quite straightforward to analyze this type of intervention in an otherwise standard RBC model. A simple model of the intermediation process, proposed by Cooper-Ejarque [1996], assumes that the technology that converts savings into new capital is a stochastic and nonlinear process. In fact, one interpretation of this structure is that government regulations, such as reserve requirements, act as a tax on the intermediation process.[9]

Letting θ represent the current value of the productivity of the intermediation process and assuming all period t+1 capital is intermediated, the conditions describing an equilibrium path are:

$$\frac{u_2(c,1-n)}{u_1(c,1-n)} = AF_2(K,n) \tag{6}$$

$$u_1(c,1-n) = \beta E u_1(c',1-n')[A'F_2(K',n')+(1-\delta)]\theta. \tag{7}$$

$$c + K'/\theta - (1-\delta)K = AF(K,n) \tag{8}$$

These conditions are quite similar to those given for the basic RBC model except that the current intermediation shock, θ_t, enters into both the Euler equation, (7), and the accumulation equation, (8). The effects of variations in the productivity of the intermediation process are fairly straightforward to see.[10] In particular, in times of productive intermediation (such as a low reserve requirement), more resources will be invested and less consumed. Further, due to the

[9]This point is also raised in Loungani-Rush [1995].

[10]Greenwood, Hercowitz and Huffman [1988] have a related model in which there are shocks to capital accumulation which they interpret as investment shocks. See their lengthy discussion of the negative correlations that can be generated in this class of models.

higher return on investment, employment will increase as well. As a result, the impact of a shock to the intermediation process is to create negative comovement between consumption and employment and between consumption and investment. Further, the transitional dynamics of the standard model reinforce this negative correlation.[11] Thus, Cooper-Ejarque find that one implication of these models in which fluctuations arise from variations in the productivity of the intermediation process is the negative comovement.[12] Further, Cooper-Ejarque find the these shocks cause capital to be more volatile than output.

From an empirical perspective, the issue is whether there is evidence of these negative correlations. For U.S. data, the unconditional correlations between consumption, investment and employment are all positive and capital is less volatile than output. Clearly, these shocks to the process of intermediation can not be the sole driving process for fluctuations. However, if one looks at particular periods in U.S. history (such as the 1966 credit crunch episode or the 1937 recession), there does appear to be some evidence of the predicted negative comovement between consumption and investment. Further, a VAR structure with dummy variables for credit crunches predicted some negative comovements in response to intermediation shocks as did the empirical work of Loungani and Rush on the effects of varying reserve requirements.

(iv) Summary

Over the past 15 years, the stochastic growth model has become a main tool for business cycle analysis. The point of this section was not to provide yet another review and critique of the

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[11] This point is discussed in some length by King, Plosser and Rebelo.

[12] Interestingly, Baxter-King [1993] find similar effects in some of their fiscal policy exercises. In fact, it is easy to see that variations in an investment tax credit would behave in a similar fashion as "intermediation shocks" on new capital expenditures. How economies actually respond to investment tax credits is an issue worthy of more study.

real business cycle structure. Rather, the goal was to describe some of the links between those models and policy questions. In particular, the discussion points to a number of policy exercises within the real business cycle structure that ought to be informative to policymakers considering the impact of a wide variety of fiscal and monetary interventions.

Still, considerable doubt remains over the value of the strict RBC model for understanding business cycles. The complete contingent markets model with fluctuations driven by technology shocks that formed the basis of the earlier analysis is far less universally accepted than the methodology itself. Further, some of the criticisms raised early on concerning the predominance of technology shocks have not been adequately addressed. While, for example, the standard RBC model seems consistent even with the Great Depression in the U.S., it is hard to imagine that technological regress was at the heart of this deep and prolonged downturn. Even taking the models as given, problems matching certain labor market observations and concern over measure of the Solow residual (as in Burnside, Eichenbaum and Rebelo [1995]) leaves wide open the age old questions of the source and welfare consequences of fluctuations.

While these criticisms are most forceful in arguing that the RBC structure does not provide an adequate representation of the aggregate fluctuations, these concerns obviously influence the credibility of the policy implications derived from them. One might be rather reluctant to base policy advice upon a model that isn't firmly linked to the data. This does not provide a basis for rejecting the quantitative approach but instead is a call for considering alternative models.

What are the key features of the basic model that, at least in principle, are most objectionable? First, there is the assumption of complete contingent markets. Second, the standard RBC model rests too much upon the representative household structure. Finally, potentially important issues associated with nonconvexities are assumed away.

Hence, in the sections that follow, these modeling features will be emphasized. Moreover, and in keeping with the theme of this essay, we will stress some of the novel policy implications created in this alternative set of models. In particular, does the introduction of strategic interactions and heterogeneity change either the basis for policy interventions or our predictions of the consequences of policies?

III. Macroeconomic Complementarities and Multiple Equilibria

The representative agent model with complete contingent markets avoids a number of important issues. First, choices are obviously made by a multitude of agents and trade occurs in all economies. Second, perhaps it is better to think of real economic life as the interaction of heterogeneous units, each with the ability to influence the trading opportunities of others in environments where external effects are present. The tough part, at least for some macroeconomists, is not recognizing that this is a better description of reality but rather in making this approach both tractable and enlightening.

The starting point for this discussion is a simple coordination problem. Consider the following game played by a large number of agents. Each agent in the economy chooses one of two strategies. In general, payoffs for a single agent will depend on the profile of choices by all agents. For now, assume that all agents are identical so that we can focus on symmetric equilibria.[13]

[13] In this sense, we are again back to the representative agent model though only in equilibrium.

In Figure 1, let the row strategies represent the choices of a single agent and the columns the choice of all other agents. In this construction, we are using our restriction to symmetric equilibrium to simplify the payoffs. The numbers displayed in the matrix are the payoffs to the single agent given the action of that player for each possible action of <u>all</u> other players.

For this game, there are two pure strategy equilibria: (1,1) and (2, 2). From the figure, playing 1 (2) is a best response to that choice by all others. Hence, it is a pure strategy Nash equilibrium. These pure strategy equilibria are Pareto-ordered: (2,2) yields higher payoffs to all players. Despite this, a single player has no incentive for unilateral defection from the (1,1) equilibrium.

		Strategies of all others	
Single		1	2
Players	1	800	800
Strategy	2	0	1000

Figure 1: Coordination Game

In terms of macroeconomics jargon, in the Pareto inferior Nash equilibrium there are $100 bills lying on the sidewalk. This statement was often used to criticize models in which some mutually advantageous trades were not executed. Here, in this coordination game there are sub-optimal equilibria because it takes the actions of many agents to pick up the $100 bills. Thus, it is the lack of coordination among agents that underlies the unexploited gains to trade.[14]

What are the critical features of this type of game? As discussed by Cooper-John [1988]

[14]One issue, beyond the scope of this paper concerns equilibrium selection. The experimental evidence on coordination games (see, e.g., Cooper, Dejong, Forsythe and Ross [1994] and van Huyck et al. [1990]) indicates that Pareto-optimal equilibria are not always selected.

for simple games and Milgrom-Roberts [1990] and Vives [1990] for more complex environments, the key to this type of situation is a complementarity in the interactions of agents. Put simply, coordination games have a structure such that "..if others work more, a single agent will as well." With small numbers of agents, this positive interaction is often called strategic complementarity. In a macroeconomic context with a large number of agents, this is termed macroeconomic complementarity.

(ii) Sources of Complementarity

In macroeconomics, there are three main lines of research on coordination games. These avenues of investigation are distinguished by their departure from the Arrow-Debreu model.

A. Production Complementarities

The first approach, associated with the contribution of Bryant [1983], models the complementarity as stemming from the interaction of agents through the production function. Thus, if other agents work or produce more, then the remaining agent is assumed to be more productive. This will, under the restriction that input supplies are increasing in their real return, induce the remaining agent to produce more.

For example, suppose that an agent chooses a level of work (or effort) $e \in [0,1]$. The agent's preferences are given by u(c)-g(e), where u(c) is an increasing, concave function of consumption (c) and g(e) is increasing and strictly convex. Because of the production complementarity, assume that the production of consumption depends on both own work (e) and the level (or average) of work effort by others in the economy, (E). That is, let c=f(e,E), where $f(\cdot)$ is thus a production function. If $f_{12}>0$, then increases in the level of effort by all others in the economy will increase E and also increase the productivity of more effort by the single agent.

As an extreme example, let u(c)=c, $g(e)=e^2/2$ and f(e,E)=eϕ(E), where E here represents the average level of activity by all other agents. Taking E as given, the best response of the single agent is to set e=ϕ(E), so that ϕ(E) is the best response function of the agent. If ϕ(E) is an increasing function, then $f_{12}>0$. Equivalently, we are in a situation of strategic complementarity. Nash equilibria are given by any value of e, call it e^*, such that $e^*=\phi(e^*)$.

Clearly, for certain functions ϕ(E), such as the logistic function, it is quite easy to obtain multiple equilibria using this linear-quadratic specification of preferences. Since increases in activity lead to higher productivity for the single agent, these equilibria will be Pareto ranked.

Bryant [1983] considers a related example in which the production function is given by f(e,E)=min(e,E). While this is not a continuously differentiable function, it still has the important property of complementarity: if other agents work more, my effort is more productive too.[15] When u(c) is strictly increasing and strictly concave and g(e) is strictly increasing and strictly convex, then there will exist a unique effort level, call it e^{**}, which represents the social optimum. Bryant proves that the set of symmetric Nash equilibria includes any effort level between 0 and e^{**}. Thus in this extreme case, the set of Nash equilibria is a continuum. As was the case before, these equilibria can be Pareto-ranked.

B. Search Models

Starting with Diamond [1982], macroeconomists have explored the importance of increasing returns in the search process as a basis of complementarity. Here we can think of search quite generally to encompass any form of trading frictions. The key aspect of this approach is that these costs of trading fall as the number (fraction) of traders increase. That is,

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[15]For the approach of Milgrom-Roberts [1990], the min function is a prime example.

there is a thick market effect operating through the magnitude of these frictions.

In Diamond's model, agents have a choice of undertaking an expensive project. There is heterogeneity in the economy; some projects are more expensive than others. If an agent chooses to produce, then that agent must trade output with another agent in order to consume. By this assumption that agents do not consume their own output, Diamond forces trade. In contrast to the Arrow-Debreu complete contingent markets view, trade does not occur in well-organized markets. Instead, agents must search for each other which is represented by a matching function. Diamond assumes that this matching function exhibits increasing returns to scale: the larger the fraction of agents searching, the easier it is to find a trading partner.

Using this form of increasing returns, Diamond shows that his model may have multiple Pareto-ranked equilibria. In one equilibrium, very few agents participate in the production of goods so that trading opportunities are not very good. Hence only low cost projects are undertaken. In a second equilibrium, many agents will undertake production so that, through the increasing returns, trading probabilities are relatively high. As a consequence, both low and higher cost projects are undertaken. That the equilibria are Pareto-ordered arises from the fact that in the equilibrium with high activity, all agents that produce could have chosen not to produce thus obtaining their payoffs from the other equilibrium.

There are numerous other settings where the elements of Diamond's structure create the possibility of coordination failures.[16] All of these models have a couple of key ingredients: some form of market friction that is reduced in thicker markets and a discrete decision to participate in some activity.

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[16]The most well known case being the Kiyotaki-Wright [1993] model of money in a search theoretic setting. González [1996] provides an example in which increased market participation by some agents increases the informativeness of signals and thus induces participation by others.

(iii) Imperfect Competition

A final area of investigation for coordination games arises in models of imperfect competition. Here the departure from the Arrow-Debreu model comes from the introduction of market power, principally to the sellers of goods.

Consider an economy consisting of many sectors producing distinct goods. Each sector consists of a few firms producing the same product who interact in the market for their homogenous product. The demand for their product reflects, among other things, the activity levels of firms in the other sectors. Firms take their sectoral demand curve as given, as they are small relative to the rest of the economy. This is essentially the structure of Hart [1982].

Suppose that firms play a Cournot-Nash game within a sector; they choose output given the output levels of others. This interaction is well-defined interaction and generally there is an equilibrium for a sector **given sectoral demand.** In fact, the interaction of firms within a sector is one of strategic substitutability; as other firms expand, the remaining firm will contract output.

However, the interaction across sectors is generally one of strategic complementarity. As firms in other sectors expand their production levels, the demand curve facing a given sector will shift out, inducing firms in that sector to expand as well. Thus the complementarity arises quite naturally from the normality of goods.

In the presence of imperfect competition, this complementarity creates the basis for a coordination game. Heller [1986] and Cooper [1994] construct examples of multiple, Pareto-ranked equilibria in this type of economy while Kiyotaki [1988] generates multiplicity in a related model of monopolistic competition.

(iii) Positive Implications

Perhaps not surprisingly, the specification of the complementarities model that has received most attention in the quantitative macroeconomics literature is the production externality model. This largely reflects its tractability and the ease of placing it in the context of a stochastic growth model. However, the development of this approach will undoubtedly require consideration of alternative sources of complementarity along with microeconomic and macroeconomic evidence.

The Baxter-King [1991] specification fits neatly into our discussion of stochastic growth models. Consider the household optimization problem specified in (1)-(2) assuming that all fiscal policy variables are set to 0. Further, suppose the production technology of an individual producer is given by

$$y_t = A_t F(k_t, n_t) Y_t^{\epsilon} . \tag{9}$$

In the specification Y_t represents the economy wide average level of output while y_t represents output for a particular individual. Being small, the individual firm takes Y_t as given in optimizing. In (9),ϵ measures the magnitude of the effect of average activity on the productivity of a single agent. This specification is one simple representation of the Bryant style production complementarity in which high activity by others makes the remaining individual more productive.

With this production function in mind, solution of the individual's intertemporal optimization problem will yield decision rules for employment, consumption and capital accumulation given the state contingent process for aggregate output. The set of first order conditions are:

$$\frac{u_2(c,1-n)}{u_1(c,1-n)} = AF_2(k,n)Y^{\epsilon} \tag{10}$$

$$\beta E u_1(c',1-n')[A'F_1(k',n')(Y')^{\epsilon} + (1-\delta)] = u_1(c,1-n) \tag{11}$$

and

$$k' = k(1-\delta) + AF(k,n)Y^{\epsilon} - c. \tag{12}$$

Since there are no differences across agents, an equilibrium arises when the individual and aggregate processes coincide. So in (10)-(12), determining an equilibrium amounts to imposing the restriction that the choices of the single agent and the average agent coincide. This, combined with a Cobb-Douglas specification of the technology leads to a final set of equilibrium conditions.

A key step is parameterization of the model, particularly the size of the production externality. Baxter-King use an instrumental variables estimation routine on aggregate data to identify this parameter. The instruments chosen are arguably independent of any technology shock in the economy to enable identification. From this exercise, they set ϵ at .23.[17] However, these estimates have been widely disputed and remain a topic of continued research.

Given this model, there are two questions that are addressed. First, does the introduction of technological spillovers into the basic growth model improve its ability to mimic key features of the business cycle? Second, does this model accommodate other sources of fluctuations?

On the first question, a model with production complementarity will tend to magnify an

[17] Cooper-Haltiwanger [1993] describes the estimation issues in some details and discusses an attempt by Braun-Evans [1991] to estimate this parameter using seasonal data. The use of seasonal data is a natural way to identify the social returns to scale since one would generally not argue that seasonal fluctuations are predominantly due to technology shocks. More recent evidence by Basu-Fernald [1995] questions conclusions based on the use of value added data in these exercises.

underlying technology shock. When technology improves for exogenous reasons, the increased activity by each agent will cause aggregate activity to increase which, acting through the complementarity, will magnify the initial shock. This interaction can be seen directly in (11) where the level of output by others acts like a shock to total factor productivity. The complementarity does not do much in terms of adding persistence to the economy.[18]

On the second point, Baxter-King also consider adding taste shocks to the model through exogenous variations in the marginal utility of consumption. Using the model with external returns to scale and taste shocks alone, Baxter-King report that the model produces: (i) positively correlated fluctuations in the key components of aggregate GNP, (ii) fluctuations which are persistent in terms of their deviations from trend and (iii) consumption which is less volatile than output which is, in turn, less volatile than investment. These are the same features that are prominently displayed by models which are driven by technology shocks. The novelty of the Baxter-King exercise is that quite similar implications arise in models with demand shocks if there are external increasing returns to scale.

Overall, this specification shows that the presence of complementarities can magnify shocks. Further, demand shocks may be consistent with procyclical productivity when large enough complementarities exist. In fact, bringing together versions of these models in which complementarities magnify and propagate shocks with more reasonable sources of fluctuations, such as monetary or fiscal shocks, would be a fruitful avenue to pursue.

Note that while the Baxter-King formulation contains a complementarity in production, this is not an economy with multiplicity. We now turn to other efforts which look at the

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[18] Cooper-Johri [1996] estimates a model with dynamic complementarities which does produce considerable persistence.

quantitative implications of multiple equilibria and thus the independent role for beliefs as a source of fluctuation.

One form of multiplicity and sunspot equilibria arises in models with multiple steady state equilibria. Cooper-Ejarque [1995] looks at a version of the stochastic growth model in which intermediaries play a critical role in the process of capital accumulation. In this formulation, there are increasing returns to scale in the intermediation process that leads to a multiplicity of steady states. In one steady state, agents are pessimistic about the returns to intermediated activity and thus do not invest. The low level of intermediated activity leads to an unproductive process and thus this equilibrium is self-fulfilling. Similarly, there is another equilibrium in which the intermediation process is quite productive and this is consistent with a high level of intermediated activity.

The main contribution of the Cooper-Ejarque paper is to look at the positive implications of the multiplicity of steady states. They construct a sunspot equilibrium as a basis of randomizing between the two steady states and then study quantitatively the implications of the model. The structure is highly non-linear due to the multiplicity and thus an important aspect of the analysis is dealing with the regime shift structure. Cooper-Ejarque argue that their model is consistent with some aspects of the U.S. Great Depression period, though, as in the linearized version of the model discussed earlier, the model still implies too much negative correlation across consumption, employment and investment relative to observations over the 1920-40 period.

Benhabib-Farmer [1994] and Farmer-Guo [1994] take the Baxter-King specification an additional step and investigate a second form of multiplicity in a dynamic model. In an economy with very elastic labor supply, a production complementarity considerably larger than that used by

Baxter-King and a slightly larger labor share, Benhabib-Farmer and Farmer-Guo argue that the basic neoclassical growth model has sunspot equilibria. That is, with this parameterization, the steady state is no longer a saddle. Instead, it becomes a sink and thus there are multiple paths leading to the steady state. With this structure, it is possible to randomize across paths and thus generate sunspot equilibria.

Farmer-Guo [1994] evaluate the quantitative implications of these sunspots. The introduction of the sunspots essentially adds a bit of noise to the intertemporal Euler equation. Farmer-Guo find that their model possesses many of the same properties of the basic RBC model: there is evidence of consumption smoothing and investment is more volatile than output. More interestingly though, the sunspot model generates serial correlation in output, consumption and investment with iid shocks. That is, in contrast to other models, the sunspot structure generates endogenous persistence. Further, due to the strong external returns, the model also generates procyclical productivity.

To return to the issue of wage and price rigidity, the model with production externalities has also been used to investigate price rigidity and monetary shocks by Beaudry-Devereux [1993]. Interestingly, they use the multiplicity of equilibria to support an outcome where money is not neutral. That is, among the set of equilibria, there is one in which prices are predetermined. In this way, the ex post price rigidity is generated as part of the equilibrium rather than through an outside assumption.[19] Further, the large returns to scale creates a basis for the propagation of the monetary shocks. Thus, Beaudry-Devereux are able to match the observed implications of positive monetary shocks: output, consumption, investment and employment rise, interest rates

[19] Cooper [1990] argues that equilibria with predetermined wages and prices exist in a bilateral contracting model since these contracts jointly provide insurance to risk adverse workers.

initially fall and average labor productivity rises.

(iv) Policy Implications

One of the interesting aspects of models based upon macroeconomic complementarities are their policy implications. In contrast to the RBC model, there are real gains to coordination in these models. Put differently, the multiplicity of equilibria allows for a positive coordinating role for the government. In fact, this need not be an active role in the sense of spending and taxation. Instead, the government can provide confidence and thus influence the choice of an equilibrium in the event of multiplicity. At the same time, the presence of the government may itself provide an additional source of instability.

The role of the government as a stabilizer in coordination models is nicely brought out in the bank runs model of Diamond-Dybvig [1983]. As is well known, there are multiple equilibria in this model due to the illiquidity of the banking system. In one equilibrium, agents have faith and leave their funds in the banks while in another, agents lose confidence and extract their funds. There is a complementarity in that when all other agents leave (withdraw) funds, the remaining agent has an incentive to do so as well.

As discussed by Diamond-Dybvig, the government can provide confidence in the intermediation process through the introduction of deposit insurance. This effectively breaks the complementarity: even if all others withdraw their funds, the residual agent should not withdraw. Of course, in the unique equilibrium the government actually never takes any actions!

There are numerous examples though in which the presence of a government is, in fact, the source of multiplicity. Consider the static optimization problem of an agent choosing how much to work (n) to maximize $u(An(1-\tau),n)$ where A is a measure of productivity and τ is a tax rate. The agent takes the tax rate as given and the optimal choice of hours would be given by $n^*(A,\tau)$. Assume that substitution effects dominate so that $n_1>0$ and $n_2<0$. Further, suppose that the government faces a financing constraint that $\tau AN=G$, where N is the average level of employment in the economy. Hence there is an implicit relationship between taxes and activity given by $\tau(N)$ with $\tau'(N)<0$. Inserting this into the optimal employment rule yields: $n=n^*(A,\tau(N))$ with n^* increasing in N. That is, as the level of activity increases, the tax rate will fall and this will support the higher activity level. This upward sloping relationship between the action of one agent and all others is a complementarity that can lead to multiple equilibria since it generates a Laffer curve.[20]

Schmitt-Grohe and Uribe [1996] analyze multiplicity in a dynamic model in which the government must balance the budget using distortionary labor taxes.[21] In this setting, they show indeterminancy of the steady state if labor supply is sufficiently elastic. To see why, suppose that forward-looking agents anticipate high labor taxes in the future. Thus, they anticipate a lower labor input in the future and hence lower productivity of capital. From this, the current demand for investment is lower and thus output in the current period will be lower. Therefore, the government will have to raise taxes today to raise the necessary revenues to balance the budget. In a sense there is an intertemporal complementarity at work here: higher tax rates in the future lead to higher tax rates today.

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[20] An early example of this point appears in Persson and Tabellini [1990] and more recently in a growth context in Gloom and Ravikumar [1995]. Eaton [1987] analyzes a model of capital flight in which tax policies creates a complementarity across investors and thus the prospect of multiple equilibria.

[21] In a related effort, Christiano-Harrison [1996] explore the large set of equilibria for an economy with both production complementarities and government expenditures financed by income taxes with lump sum transfers used for budget balance.

IV. Heterogeneity and the Making of Economic Policy

The last class of models we consider has two key components: discrete choice at the microeconomic level and heterogeneity. From the perspective of these models, decisions at the micro level are not taken continuously but instead are taken infrequently, perhaps due to some non-convexities in the costs of adjustment. The heterogeneity arises because individuals will generally have different probabilities of acting, reflecting both the current values of relevant state variables and underlying heterogeneity across decision units.

These models are clearly much more complicated than the standard stochastic growth model due to the heterogeneity and nonconvexities. Advocates of these models argue that the complexity brings a benefit in terms of a deeper understanding of the economy's response to different shocks and a new source of propagation. Critics argue that aggregation adequately smooths over the both the non-convexities and differences across agents so that these models provide relatively little new insights into aggregate behavior.

This section of the paper will describe some examples from this class of models and provide some insights into this controversy. Then, we discuss the policy insights from models which rest upon heterogeneity and discrete choices. As we shall see, one lesson for policymakers is that the impact of interventions may be quite sensitive to current distributions of state variables across agents. A second point is that the evolution of the cross sectional distribution created by the policy intervention can be substantial and thus ought to be considered in the policy analysis.

(i) Basic Structure

A useful starting point is a generic model described by Caballero and Engel [1993]. The economy is populated by a group of agents indexed by $i=1,2,\ldots I$. At each point of time, indexed by t=1,.....T, the agent is described by two variables. The first, denoted by x_{it}, represents the current state of the agent. The second, denoted by x^*_{it} is the desired state of the agent if adjustment was costless in the period. Thus, $z_{it} \equiv x_{it} - x^*_{it}$ measures the distance between the actual and desired state of the agent.

A stationary decision rule is then some function of the current state, say $\phi(z)$. In the discrete choice setting, this decision rule has the interpretation of a hazard function: $\phi(z)$ is the probability that an agent in state z will act.[22] Note that by construction, the optimal action of an agent is to set $x_{it} = x^*_{it}$.

What are the properties of this decision rule? It is natural to conjecture that the likelihood of an agent acting is increasing in the $|z_{it}|$. The exact nature of the hazard function is generally determined in two ways. Either, one takes the hazard as a primitive object and specifies a functional form which is then estimated. Alternatively, one can start with an underlying dynamic programming problem and then generate the hazard as the optimal decision rule. These alternatives are described in more detail below in the context of a particular example. For now, we take $\phi(z)$ as given to illustrate some of the properties of the model.

The nonlinearities and propagation in the model comes from the cross sectional distribution. Let $f_t(z)$ denote the period t cross sectional distribution of z across the agents. Further, let Y_t denote the level of activity in period t. By activity, we mean the change in the variable x_{it} for all of the agents. So,

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[22] An alternative model, described by Caballero-Engel [1993] would have agents adjusting partially toward their target so that $\phi(z)$ would the magnitude of partial adjustment between the current state and the target. While these interpretations appear undistinguishable at the aggregate level, they are very different views of optimal decisions at the micro level.

$$Y_t = \int z\phi(z)f_t(z)dz. \tag{13}$$

To interpret this expression, recall that the adjustment of an agent that acts is exactly z and the probability of action is $\phi(z)$.

The dynamics of the model stem from the evolution of the cross sectional distribution. Following this distribution, however, is complicated by the interaction between choices in period t and the realization of period t+1 shocks. It is thus convenient to think of two distributions in any period. The first, which we denote by $h_t(z)$ is the distribution prior to any period t shocks. The second is ex post and given by $f_t(z)$.

After the actions in period t but prior to period t+1 shocks, the distribution of z across agents is given by:

$$\begin{aligned} h_{t+1}(0) &= \int \phi(z)f_t(z)dz , \\ h_{t+1}(z) &= [1-\phi(z)]f_t(z), \ z \neq 0. \end{aligned} \tag{14}$$

The first part of this statement refers to the agents who adjust in period t. These agents comprise the group with z=0 at the start of the period. The second part of this expression relates to those who do not adjust in period t, so that their value of z does not change over time.

Once $h_{t-1}(z)$ is determined, there will generally be shocks, both common and agent specific, that will influence the value of each agent's z for the period. This generates the distribution $f_{t+1}(z)$ from $h_{t+1}(z)$. So, for example, after the shocks, those agents who adjusted in period t may again find that their value of x_{it} differs from the target.

With this structure in mind, we return to the themes of the response of agents to shocks and propagation. When an economy of this type is hit by a common shock, the resulting change in the distribution of z will lead to an adjustment by some agents and not by others, dictated by the shape of $\phi(z)$. Further, the response of those who act is much larger than the average response across agents. This suggests, as pursued by Caballero, Engel and Haltiwanger [1995b] that individual's behavior is much more elastic with respect to, say, relative prices than one sees by looking at aggregate behavior.

There is also a nonlinear response to shocks in these models. By nonlinearity we mean that the response of the model to a shock will depend on elements of the current state, particularly the distribution. So, the effects of a common shock that, say, reduces the values of z for all agents will depend on the distribution of z prior to the shock. For some distributions, the shock will cause a large fraction of agents to act and for other distributions the shock will have a much smaller influence.

As for propagation, the law of motion for the distribution summarizes the manner in which history influences current activity. From (14), even in the absence of aggregate disturbances, the level of activity will vary along with the cross sectional distribution. Of course, the magnitude and nature of the propagation will depend on the hazard function, $\phi(z)$. An important issue that we turn to below is how much propagation can actually be generated by this mechanism.

While compelling due to its generality, this structure is not quite convincing in a couple of respects. First, there is no guarantee that the actual state of the system can be so conveniently summarized through a single dimensional variable, z. Second, the hazard function is not derived directly from an optimization problem. This is problematic for certain policy analyzes, particularly those that are not encompassed by historical precedence.[23]

(ii) A Durable Goods Example

To deal with some of these potential problems and to make the linkages to policy as well as the properties of nonlinearity and propagation explicit, we turn to a specific example which comes from Adda-Cooper [1997].[24] The problem concerns the optimal scrapping of cars and the policy exercise relates to recent attempts in some countries, such as France, to stabilize the automobile market by subsidizing the scrapping of cars.

Consider the problem of an individual household owning a car of age i. The household enjoys a service flow from this good given by s_i and also gains utility from other goods, denoted by c. Assume that households have either 0 or 1 cars. Each period, the household can keep the car, sell it or scrap it. In the event of a sale or a scrapping, a new car may be purchased. If we assume for now that all households are identical except for the age of their car, then in equilibrium there will be no trades of intermediately aged cars.

The household's discrete dynamic choice problem is then to choose between retaining the car and scrapping it. Letting, c denote the cost of a new car, y the income of the household and π the scrap value of a car, the dynamic programming problem is given by:

$$\begin{aligned} V_i(c,y,\pi) = \max(&u(s_i,y)+\beta EV_{i+1}(c',y',\pi') \,, \\ &(u(s_1,y+\pi-c)+\beta EV_2(c',y',\pi')) \,. \end{aligned} \tag{15}$$

[23] That is, a government may wish to implement certain policies that have no historical precedent making predictions of their effects impossible without knowing underlying decision rules.

[24] This same structure is used by Cooper-Haltiwanger [1993] and Cooper, Haltiwanger and Power [1996] to study lumpy investment. See Bar-Ilan and Blinder [1992] for further motivation on the appropriateness of discreteness.

In this problem, V_i is the value of an agent of an age i car. The agent can hold that car and earn a utility flow of $u(s_i,y)$ within the period and then have a car of age i+1 in the next period. Alternatively, the agent can scrap the car and buy a new one at cost c and then have a car of age 2 in the following period. Note that this construction assumes that the utility from car ownership exceeds the cost of a new car, c. The state of the system is given by the age of a particular agent's car and the common variables (c,y,π), which we define as z.

As shown in Adda-Cooper [1997], the solution to (15) takes the form of a stochastic stopping problem: for each value of the state vector, there is a critical age, denoted I(z) such that cars are scrapped iff i>I(z). Using the notation developed above, let $\phi_i(z)$ be the probability of scrapping and buying a new car in state z if the current car age is i. Note that since z includes the entire set of variables influencing the individual's choice, $\phi_i(z)\in\{0,1\}$. If there are unobservable components to the agent's problem not included in z, such as taste shocks, then $\phi_i(z)\in[0,1]$. In this case, $\phi_i(z)<\phi_{i+1}(z)$ for all z; i.e. the hazard is increasing in car age.

As in (14), the level of new car sales is determined by the interaction between the hazard and the cross sectional distribution over the car ages, $f_t(i)$. So, given the realized aggregate shocks (c,y,π), the level of new car sales is given by:

$$Q_t = \sum_{i=1}^{I^{max}} \phi_i(z) f_t(i) \tag{16}$$

where I^{max} is the oldest optimal scrapping age and hence the oldest car held while i=1 is a new car.

For this simpler model, the evolution of the cross sectional distribution is easier to follow. That is,

$$f_{t+1}(1) = Q_t, \quad f_{t+1}(i+1) = (1-\phi_i(z))f_t(i) \ . \tag{17}$$

The factors that determine the sensitivity of durables purchases to variations in the aggregate variables are now easy to see. Consider the effects of shocks to aggregate income. In this model, variations in income will influence the hazard for cars of age i. From an analysis of (15) with a two-state income process, Adda-Cooper [1997] find that $\phi_i(z)$ is increasing in income.

From (16), the impact of the income shocks on car sales will depend partly on the magnitude of the hazard shift and partly on the cross sectional distribution of the car vintages at the time of the shock. This is precisely the source of nonlinearity. If there are many new cars in the population then a high income realization will lead to a relatively small increase in new car sales.

Following this income shock, the dynamics of the cross sectional distribution will take over. In general for these models, the transitional dynamics are dampened cycles.[25] To see why, suppose that the initial cross sectional distribution places considerable weight on young cars. Given that the hazard is increasing in car age, car sales will be low. Overtime, the age distribution will adjust with more weight placed on older cars. This will increase car sales. Eventually, the population of cars will again be fairly young and car sales will be relatively low.

While Adda-Cooper investigate this problem by solving (15) numerically, suppose that the hazard is simply a logistic function of the form:

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[25] See Bar-Ilan and Blinder [1992] for an earlier argument of this point. Cooper, Haltiwanger and Power [1996] discuss this in some detail for an investment example. As pointed out by Jess Benhabib, the cyclical nature of these models dates to at least Marx's interest in replacement cycles.

$$\phi(z) = \frac{e^{\alpha+\beta*Y+\gamma*i}}{1+e^{\alpha+\beta*Y+\gamma*i}} \tag{18}$$

where Y is the state of aggregate income and i is the age of the car. So here prices and scrap values are assumed constant and are thus incorporated in α. Assume that Y takes on two values, $Y_H > Y_L$, with the evolution of these random variables given by a symmetric transition matrix with .9 along the diagonal.

For the numerical analysis that follows, the constant term was set to 0, β was set at 1 and the value of γ was chosen so that the average age of cars is about 6, as in French data. For this parameterization, the two hazards are shown in Figure 2.

Figure 3 shows the time series of sales from a simulation of the model to illustrate both the nonlinear response of sales to income shocks and the cyclical nature of the propagation mechanism. Note from the figure that the response of sales to a change in state from low to high, as in periods 12 and 28, is not the same. This reflects the fact that sales depends jointly on the cross sectional distribution and the income state. Between the changes in state, sales are determined by the evolution of the cross sectional distribution. After the high income shock in period 28, sales are low though after period 31, they rise slowly as the stock of cars begins to age. In this sense, shocks are propagated over time.[26]

This example can also be used to discuss the effects of government policies in this environment. Adda-Cooper consider a more complicated version of this model to study the impact of policies in the automobile market undertaken recently in Europe. In particular, the

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[26] The time series process for sales though is quite complicated. For example, if the income shocks are independent, there is still propagation of the shocks through the distribution. However, this is not picked up by a simple AR(1) representation for sales.

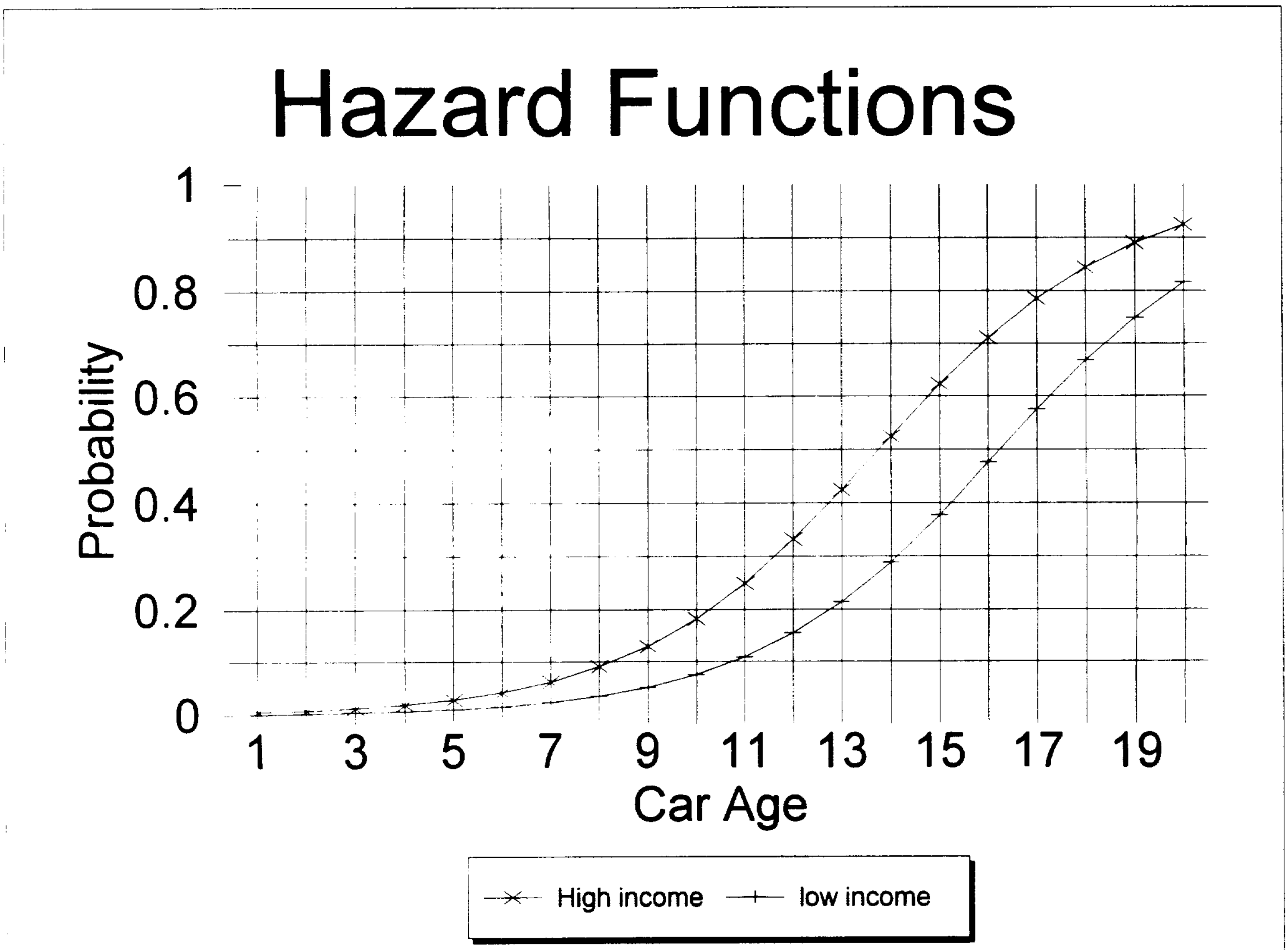
Hazard Functions
Probability
1
0.8
0.6
0.4
0.2
0
1
3
5
7
9
11
13
15
17
19
Car Age
High income
low income

Figure 2

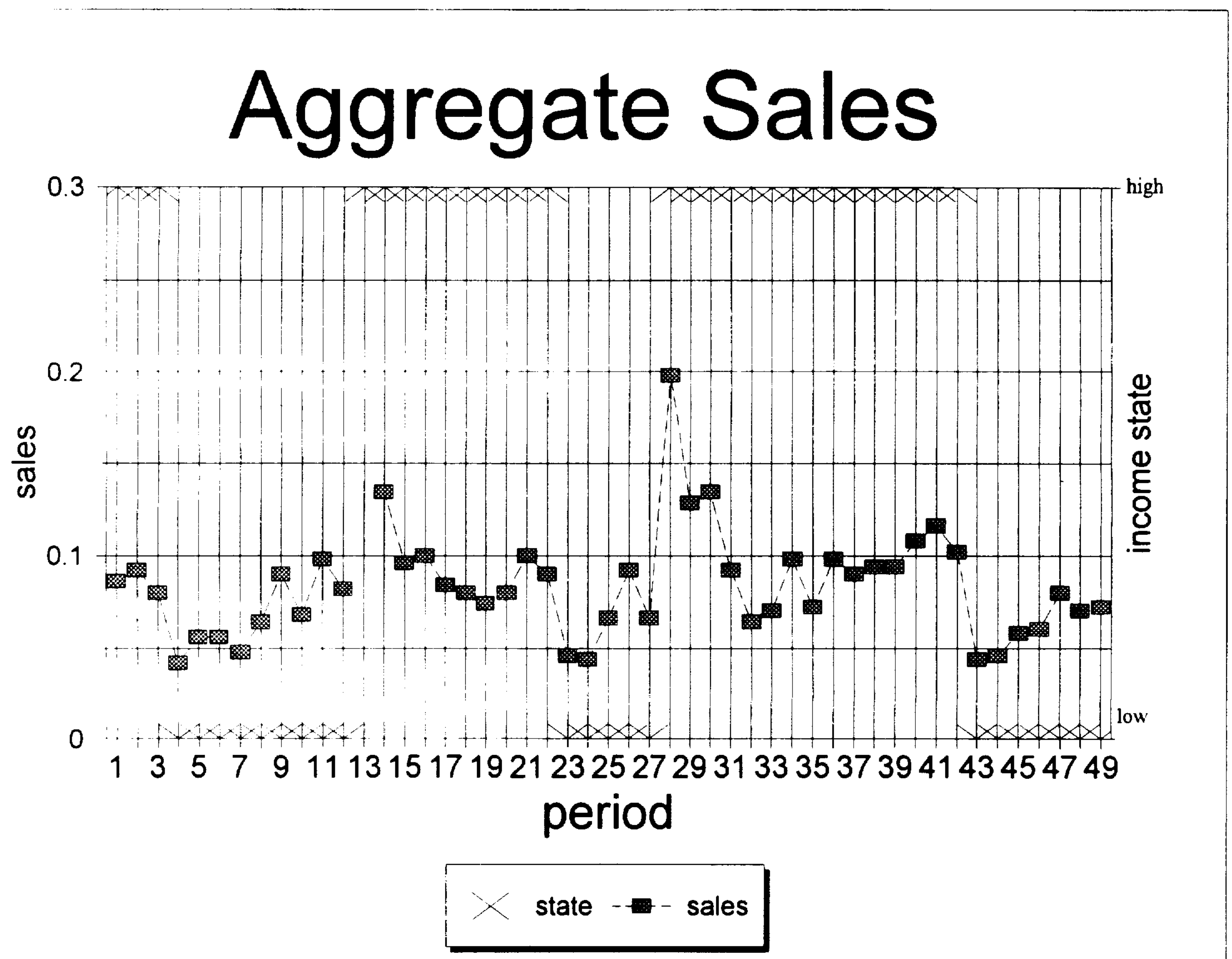
Aggregate Sales
0.3
0.2
0.1
0
sales
high
low
income state
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49
period
state
sales

Figure 3

French and Spanish governments have provided subsidies for the scrapping of old cars in the event agents then purchase new ones. In the context of the model, this is simply a variation in the scrap value, π.

Evaluating the impact of these types of policies is quite difficult. One approach would be to specify a hazard function which included a scrapping subsidy as an argument. However, for some policy exercises, such as the case of these subsidies in France, the novelty of these policies precludes this approach. Instead, Adda-Cooper estimate the parameters of preferences from the dynamic programming problem, (15), and then use these estimates to simulate the effects of the policy on sales and government revenues.

The points raised above concerning nonlinear responses and dynamics appear in the policy exercise. First, to forecast the impact of the policy on sales requires some knowledge of the cross sectional distribution of car vintages as well as the ability to predict the shifts in the hazard functions. Scrapping subsidies when the population of cars is relatively young are not very effective since the policy will not induce considerable additional sales.

Second, the stimulative effects of these policies can be rather short lived. That is, a successful policy will lead quickly to a distribution with relatively young cars and thus relatively little new sales until the young stock ages. The resulting pattern of boom and bust is not quite what one means by "stabilization policy"!

(iii) Price Rigidities Revisited

Another application of the dynamic stochastic discrete choice framework concerns price setting behavior by firms. Imagine a decentralized economy in which firms face a lump sum cost of changing their prices. At the start of each period, a firm would choose to adjust it price or not, recognizing the influence of this choice on the firm's state in the future. This choice of adjusting or not adjusting is very close to the replacement problem described above. In fact, one could directly embed this into a dynamic programming problem similar to (15), allowing a wide variety of aggregate and idiosyncratic shocks to influence the pricing decision of the firm.[27] That is, consider:

$$\begin{aligned} v(p,P,M,\theta) = \max\ [&\pi(p,P,M,\theta) + \beta E v(p,P',M',\theta'), \\ &\max_x \pi(x,P,M,\theta) - F + \beta E v(x,P',M',\theta')\ ]. \end{aligned} \tag{19}$$

Here p is the current price for a firm, P is a measure of aggregate prices, M is the stock of money and θ represents an idiosyncratic shock to the firm's current profits, represented by $\pi(p,P,M,\theta)$. The first line entails no price change by the firm so that its price in the next period is also p. The second line allows the firm to optimally choose a new price (x) but the firm pays an adjustment cost of F. To solve this dynamic programming problem requires the firm to know the distribution of exogenous random variables (M,θ) as well as the state contingent evolution of the aggregate price level, P. This is a big issue since it requires the solution of an equilibrium problem along with the optimization problem of an individual firm.

Dotsey, King and Wolman [1996] makes progress on this problem. Their firm's solve an optimal price setting problem where the fixed cost of changing a price is random across firms. As in the car example, the state of a firm is partially determined by the time since its last price change. For their economy, Dotsey et al. argue that there is a maximal time between price changes which creates a finite state space for their analysis: they follow the distribution of firms in each of these

[27]Caballero-Engel [1993c] makes essentially the same point using the gap between actual and desired price as a proxy for the firm's current state and then investigating the implications of an (S,s) rule.

states to characterize their equilibrium. With this structure, they can evaluate a number of monetary policy experiments and compare the properties of their economy to the more traditional, but less convincing, time dependent rules. Dotsey et al. find that less persistent money shocks have larger real impacts since most firms will not pay the cost of adjustment given the temporary nature of the shock. Further, their economy displays underlying cycles as part of the transitional dynamics, just as the car example given above. Finally, their economy also generates some persistence through the evolution of the cross sectional distribution.

V. Concluding Thoughts

In the U.S., the IS/LM model is now rarely taught above the intermediate undergraduate level. Yet, in the corridors of our capital and the columns of our newspaper, the implicit (and often explicit) model that underlies economic conversation is, in fact, the basic IS/LM model with a Phillips curve. Is this ever present gulf a sign of the failure of researchers to communicate their discoveries to policymakers or is it simply evidence that, in terms of policy questions, macroeconomics have made little progress over the past years?

My reading of recent literature suggests that policy relevant contributions are being made. The basic RBC model has provided us with tools for evaluating the positive aspects of a variety of fiscal policies. Further, quantitative research has gone well beyond the complete contingent markets, representative agent paradigm and will eventually allow us, in principle, to understand the impact of policy in a very rich set of alternative environments.[28] This same methodology has

[28] One could, for example, consider fiscal policy experiments in a version of the Baxter-King model and undertake an analysis of optimal policy in that environment.

been extended to study economies with price rigidities, providing additional insights into the effects of monetary policy.

Finally, the models with heterogeneity provide a novel perspective on policy. These models suggest that it is important to know the cross sectional distribution of relevant variables in assessing the impact of a particular policy. Further, these models suggest that policymakers should be aware of both the immediate and more long run implications of these actions through the dynamics induced by the cross sectional distribution.

References

Adda, J. and R. Cooper, "Balladurette and Juppette: A Discrete Approach," mimeo, Boston University, 1997.

Bar-Ilan, A. and A. Blinder, "Consumer Durables: Evidence on the Optimality of Doing Nothing," Journal of Money, Credit and Banking 24 (1992), 253-72.

Basu,S. and J. Fernald, "Are Apparent Productive Spillovers a Figment of Specification Error?" Journal of Monetary Economics,36 (1995), 165-88.

Baxter, M. and R. King, "Productive Externalities and Business Cycles," Institute for Empirical Macroeconomics, Federal Reserve Bank of Minneapolis, Discussion Paper #53, November 1991.

____________."Fiscal Policy in General Equilibrium," American Economic Review, 83 (1993), 315-34.

Beaudry, P. and M. Devereux, "Monopolistic Competition, Price Setting and the Effects of Real and Monetary Shocks," mimeo, 1993.

Benhabib, J.and R. Farmer, "Indeterminacy and Increasing Returns, Journal of Economic Theory, 63 (1994), 19-41.

Bertola, G. and R. Caballero, "Kinked Adjustment Costs and Aggregate Dynamics" in NBER Macroeconomics Annual, vol. 5, ed. by O. Blanchard and S. Fischer, Cambridge, Mass.:MIT Press, 1990.

Braun, T. "Tax Disturbances and Real Economic Activity in the Postwar United States," Journal of Monetary Economics, 33 (1994), 441-62.

Braun, T. and C. Evans, "Seasonal Solow Residuals and Christmas: A Case for Labor Hoarding and Increasing Returns," Working Paper WP-91-20, Federal Reserve Bank of Chicago, October 1991.

Bryant, J.,"A Simple Rational Expectation Keynes-Type Model," Quarterly Journal of Economics, 97 (1983), 525-529.

Burnside, C., M. Eichenbaum and S. Rebelo, "Capital Utilization and Returns to Scale" in B. Bernanke and J. Rotemberg, eds., NBER Macroeconomics Annual, MIT Press:Cambridge, Ma., 1995, 67-123.

Caballero, R. and E. Engel, "Microeconomic Adjustment Hazards and Aggregate Dynamics," Quarterly Journal of Economics, 108 (1993a), 359-84.

___________________,"Explaining Investment Dynamics in U.S. Manufacturing: A Generalized (S,s) Approach", mimeo, December 1993b.

___________________,"Heterogeneity and Output Fluctuations in a Dynamic Menu-Cost Economy," Review of Economic Studies, 60 (1993), 95-119.

______________ and J. Haltiwanger, "Aggregate Employment Dynamics: Building from Microeconomic Evidence", NBER Working Paper No. 5042, February 1995a.

______________, "Plant Level Adjustment and Aggregate Investment Dynamics", Brookings Paper on Economic Activity,2 (1995b), 1-39.

Chari, V.V., L. Christiano and P. Kehoe, "Optimal Fiscal Policy in a Business Cycle Model," Journal of Political Economy, 102 (1994), 617-652.

Christiano, L., "A Reexamination of the theory of Automatic Stabilizers," Carnegie-Rochester Conference Series on Public Policy, 20 (1984), 147-206.

Christiano, L. and M. Eichenbaum, "Current Real-Business-Cycle Theories and Aggregate Labor Market Fluctuations," American Economic Review, 82 (1992), 430-50.

Christiano, L. and M. Eichenbaum, "Liquidity Effects and the Monetary Transmission Mechanism," American Economic Review, 82 (1992), 344-53.

Christiano, L., M. Eichenbaum and C. Evans, "The Effect of Monetary Shocks: Evidence from the Flow of Funds," Review of Economics and Statistics, 78 (1996), 78-93.

Christiano, L. and S. Harrison, "Chaos, Sunspots and Automatic Stabilizers," Federal Reserve Bank of Minneapolis Staff Report 214, August 1996.

Cooper, R. "Predetermined Wages and Prices and the Impact of Expansionary Government Policy," Review of Economic Studies, 57 (1990), 205-14.

Cooper, R. "Equilibrium Selection in Imperfectly Competitive Economies with Multiple Equilibria," Economic Journal, 104 (1994), 1106-23.

Cooper, R., DeJong, D., Forsythe, R. and Ross,T. "Alternative Institutions for Resolving Coordination Problems: Experimental Evidence on Forward Induction and Preplay Communication" in Problems of Coordination in Economic Activity ed. by James W. Friedman, Boston: Kluwer Academic Publishers, 1994.

Cooper, R. and J. Ejarque, "Financial Intermediation and the Great Depression: a Multiple Equilibrium Interpretation," Carnegie-Rochester Conference Series on Public Policy, 43 (1995), 285-323.

___________," Financial Intermediation and Aggregate Fluctuations: A Quantitative Analysis," revised version of NBER Working Paper #4819, July 1996.

Cooper, R. and J. Haltiwanger, "The Aggregate Implications of Machine Replacement: Theory and Evidence," American Economic Review, 83 (1993), 360-82.

Cooper, R., J. Haltiwanger and L. Power, "Machine Replacement and the Business Cycle: Lumps and Bumps", NBER Working Paper #5260, Sept. 1995

Cooper, R. and A. John, "Coordinating Coordination Failures in Keynesian Models," Quarterly Journal of Economics, 103 (1988), 441-63.

Cooper, R. and A. Johri, "Dynamic Complementarities: A Quantitative Analysis," NBER Working Paper #5691, July 1996.

Danthine, J.P. and J. Donaldson, "Methodological and Empirical Issues in Real Business Cycle Theory," European Economic Review 37 (1993), 1-35.

Diamond, D. and P. Dybvig, "Bank Runs, Deposit Insurance and Liquidity," Journal of Political Economy,91 (1983), 401-19.

Diamond, P. "Aggregate Demand Management in Search Equilibrium," Journal of Political Economy, 90 (1982), 881-94.

Dotsey, M., R. King and A. Wolman, "State Dependent Pricing and the General Equilibrium Dynamics of Money and Output," mimeo, University of Virginia, October 1996.

Eaton, J. "Public Debt Guarantees and Private Capital Flight," World Bank Economic Review, 3 (1987), 377-95.

Eberly, J. "Adjustment of Consumers' Durables Stocks: Evidence from Automobile Purchases," Journal of Political Economy, 102 (1994), 403-36.

Farmer, R. and J.T. Guo, "Real Business Cycles and the Animal Spirits Hypothesis," Journal of Economic Theory, 63 (1994), 42-72.

Fiorito, R. and T. Kollintzas, "Stylized Facts of Business Cycles in the G7 from a Real Business Cycles Perspective," European Economic Review, 38 (1994), 235-69.

Fuerst, T. "Liquidity, Loanable Funds and Real Activity," Journal of Monetary Economics, 29 (1992), 3-24.

Gali, J. "Government Size and Macroeconomic Stability," European Economic Review, 38 (1994), 117-32.

Gloom, G. and B. Ravikumar, "Endogenous Public Policy and Multiple Equilibria," European Journal of Political Economy, 11 (1995), 653-62.

González, F. "Individual Experimentation and Aggregate Fluctuations," Boston University, mimeo, 1996.

Greenwood,J., Hercowitz, Z. and G. Huffman,"Investment, Capacity Utilization and the Real Business Cycle," American Economic Review, 78 (1988), 402-17.

Hairault, J-O., F. Langot and F. Portier, "On the Effectiveness of Automatic Stabilizers",MAD, Univ. de. Paris I, mimeo, September 1995.

__________ "Financing Unemployment Benefits in the Business Cycle: Stabilization, Welfare and Equity Issues," MAD, Univ. de Paris I, mimeo, Oct. 1996.

Hall, R "Market Structure and Macroeconomic Fluctuations," Brookings Papers on Economic Activity, 1986, 285-322.

Harsanyi, J. and R. Selten, A General Theory of Equilibrium Selection in Games, Cambridge: Cambridge University Press, 1988.

Hart, O. "A Model of Imperfect Competition with Keynesian Features," Quarterly Journal of Economics, 97 (1982), 109-38.

Heller, W. "Coordination Failure Under Complete Markets with Applications to Effective Demand," in Equilibrium Analysis, Essays in Honor of Kenneth J. Arrow , Volume II, edited by Walter Heller, Ross Starr and David Starrett, Cambridge: Cambridge University Press, 1986.

Howitt, P. "Transactions Costs in the Theory of Unemployment," American Economic Review, 75 (1985), 88-101.

Jonsson, G. and P. Klein, "Stochastic Fiscal Policy and the Swedish Business Cycle," forthcoming, Journal of Monetary Economics, 1996.

King, R., C. Plosser and S. Rebelo, "Production Growth and Business Cycles," Journal of Monetary Economics, 21 (1988), 195-232.

Kiyotaki, N. "Multiple Expectational Equilibria under Monopolistic Competition," Quarterly Journal of Economics, 103 (1988), 695-714.

Kiyotaki, N. and R. Wright, "A Search Theoretic Approach to Monetary Economics," American Economic Review, 83 (1993), 63-77.

Kohlberg, E. and J. Mertens, "On The Strategic Stability of Equilibria," Econometrica, 54 (1986), 1003-38.

Kydland, F. and E. Prescott,"Time to Build and Aggregate Fluctuations", Econometrica, 50 (1982), 1345-70.

Lee, B.S. and B. Ingram, "Simulation Estimation of Time-Series Models," Journal of Econometrics, 47 (1991), 197-205.

Loungani, P. and M. Rush, "The Effectos of Changes in Reserve Requirement on Investment and GNP," Journal of Money,Credit and Banking, 27 (1995),511-26.

Lucas, R. "Liquidity and Interest Rates," Journal of Economic Theory, 50 (1990), 237-64.

McGratten, E., "The Macroeconomic Effects of Distortionary Taxation," Journal of Monetary Economics, 33 (1994), 573-601.

Milgrom, P. and J. Roberts, "Rationalizability, Learning and Equilibrium in Games with Strategic Complementarities" Econometrica, 58 (1990), 1255-78.

Persson, T and G Tabellini, Macroeconomic Policy, Credibility and Politics, Harwood Academic Press: New York, 1990.

Schmitt-Grohe, S. and M. Uribe,"Balanced Budget Rules, Distortionary Taxes and Aggregate Instability," mimeo, Federal Reserve Board of Governors, 1996.

Vives, X. "Nash Equilibrium with Strategic Complementarities," Journal of Mathematical Economics, 19 (1990), 305-321.

Van Huyck, J.B., Battalio, R. and Beil, R. (1990). "Tacit Coordination Games, Strategic Uncertainty and Coordination Failure, American Economic Review, vol. 80, pp. 2134-48.

Weil, P. "Increasing Returns and Animal Spirits," American Economic Review, 79 (1989), 889-94.

Weitzman, M. "Increasing Returns and the Foundation of Unemployment Theory", Economic Journal 92 (1982), 787-804.